

CLAIMS:

1. A simulator or measurement apparatus for use in a ball game where a ball is hit from a stationary position, the apparatus including a ball, a connecting means, a base and a measurement means, wherein the ball is connected by the connecting means to the base, characterised in that the connecting means is operable to provide a plurality of degrees of freedom to the movement of the ball; the connecting means is substantially in a unique arrangement for each position of the ball; and the connecting means is operable to allow the connected ball, when struck by an object, to substantially replicate some or all of the motion characteristics of an unconnected ball, over a distance sufficient to measure such motion characteristics, and where the measurement means is operable to measure motion characteristics of the connected ball over the distance when such motion characteristics are substantially replicated.
- 15 2. A simulator or measurement apparatus according to Claim 1, wherein the connecting means comprises members of rigid construction.
- 20 3. A simulator or measurement apparatus according to Claim 1 or Claim 2, wherein the connecting means is operable to provide at least three degrees of freedom; and a replicated motion characteristic is substantially straight line movement.
- 25 4. A simulator or measurement apparatus according to any of the preceding claims, wherein the connecting means comprises a plurality of joints; the joints are interconnected in series, with interconnecting members between each joint; and an interconnecting member connects the ball to a first of the joints and an interconnecting member connects a last of the joints to the base.
- 30 5. A simulator or measurement apparatus according to Claim 4, wherein one or more of the joints are pivot joints; and each pivot joint is operable to rotate in one plane.

6. A simulator or measurement apparatus according to any of the preceding claims, wherein two joints are pivot joints which allow partial rotation in a substantially horizontal plane; and one joint is a pivot joint which allows partial rotation in a substantially vertical plane.

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7. A simulator or measurement apparatus according to Claim 6, wherein the pivot joint nearest the ball allows partial rotation in a substantially vertical plane.

8. A simulator or measurement apparatus according to Claim 6, wherein the pivot joint 10 nearest the base allows partial rotation in a substantially vertical plane.

9. A simulator or measurement apparatus according to any of claims 5 to 8, wherein the ball is free to move in three-dimensional space over the limited region where each pivot joint has its interconnected members at a relative angle which is less than 180° and where the pivot 15 joints remain capable of further rotation; and motion characteristics are measured while the ball remains in this region.

10. A simulator or measurement apparatus according to any of the preceding claims, wherein the connecting means comprises three pivot joints; the interconnected member 20 between the ball and the first pivot joint is of rigid construction; and the interconnected member between the ball and the first pivot joint is more than twice as long as any other interconnecting member.

11. A simulator or measurement apparatus according to Claim 10, wherein the first pivot 25 joint allows rotation in a substantially vertical direction; the second and third pivots each allow rotation in a substantially horizontal direction; and the angle between the interconnecting members joining the second pivot are at an angle between about 100° and 65°.

12. A simulator or measurement apparatus according to Claim 11, wherein the distance 30 between the centre of the ball and the axis of the first pivot is in the range 130 mm to 200 mm;

the distance between the axis of the first pivot and the axis of the second pivot is in the range 10 mm to 40 mm; and the distance between the axis of the second pivot and the axis of the third pivot is in the range 20 mm to 70 mm.

5 13. A simulator or measurement apparatus according to Claim 12, wherein the distance between the centre of the ball and the axis of the first pivot is 165 mm; the distance between the axis of the first pivot and the axis of the second pivot is 20 mm; and the distance between the axis of the second pivot and the axis of the third pivot is 50 mm.

10 14. A simulator or measurement apparatus according to any of Claims 5 to 13, wherein prior to the shot, the principal axis of the interconnecting member between the ball and the first pivot joint is oriented in a substantially horizontal plane and the angle, between the principal axis and the intended direction of motion of the ball, is less than 90° on the side adjacent where the ball is struck.

15 15. A simulator or measurement apparatus according to Claim 14, wherein the angle is around 78° or in a range between 73° and 83°.

20 16. A simulator or measurement apparatus according to any of Claims 5 to 15, wherein prior to the shot, the principal axis of the interconnecting member between the ball and the first pivot joint is horizontal.

25 17. A simulator or measurement apparatus according to any of Claims 5 to 15, wherein prior to the shot, the principal axis of the interconnecting member between the ball and the first pivot joint is tilted down at a small angle from horizontal in the direction from the ball to the joint.

30 18. A apparatus according to either Claim 16 or Claim 17, which includes a spring supporting means, and wherein the spring supporting means is operable to support the interconnecting member between the ball and the first pivot joint such that its principal axis is horizontal or at a small angle to horizontal, as required, prior to the shot;

the spring supporting means is operable to permit the ball and the interconnecting member between the ball and the first pivot joint to freely move vertically upwards; the spring supporting means is operable to prevent the ball and the interconnecting member between the ball and the first pivot joint from moving vertically downwards due to the force of gravity, but

5 is operable to allow it to move vertically downwards where a significantly greater force is applied; and where the spring supporting means is operable to return the ball and the interconnecting member between the ball and the first pivot joint to their original positions when the significantly greater force is removed.

10 19. A simulator or measurement apparatus according to Claim 18, wherein the spring supporting means comprises an energised spring and a spring stop; the energised spring is operable to urge the vertical movement of the ball and the interconnecting member between the ball and the first pivot joint against the force of gravity; the spring stop is operable to limit the movement of the energised spring at a position corresponding to the position of the ball and the  
15 interconnecting member between the ball and the first pivot joint when the interconnecting member between the ball and the first pivot joint is at the inclination required at the start of the shot; the spring is arranged such that its de-energising force is greater than that required to urge the ball and the interconnecting member between the ball and the first pivot joint vertically upwards against the force of gravity, but less than that required to resist a significantly greater  
20 force.

20. A simulator or measurement apparatus according to of Claims 4 to 19, wherein the movement of a joint on the connecting means is limited by a buffer means where the limits of the buffer means are outside the range of movements which are measured by  
25 the measurement means.

21. A simulator or measurement apparatus according to Claim 19 or 20, wherein the buffer means comprises one or more contact members which are connected to the supplemental-pivot and which bear against one or more contact members which are connected to the base when the  
30 supplemental-pivot is limited by the buffer means.

22. A simulator or measurement apparatus according Claim 21, wherein one of the contact faces of the contact members comprises a spring or an elastomeric material.

5    23. A simulator or measurement apparatus according to any one of Claims 4 to 22, which includes a docking means, wherein prior to the shot, the docking means is operable to dispose the ball in a starting position relative to other parts of the apparatus; the docking means comprises an engagement member fixed relative to the interconnecting member between the ball and the first joint and a corresponding engagement member fixed relative to the base; the  
10    engagement members being operable, when engaged with each other, to dispose the ball in the desired starting position prior to the shot and being operable to freely disengage when a shot is taken.

15    24. A simulator or measurement apparatus according to Claim 23, wherein the docking means comprises a male and a female engagement member; the engagement members are fully engaged when the ball is in the starting position; and the engagement members can freely withdraw from each other when the ball moves in the direction of a shot.

20    25. A simulator or measurement apparatus according to Claim 23 or Claim 24, wherein one or both of the engagement members comprises a tapering or guiding surface; and the progressive engagement of the engagement members urges the ball to the starting position.

25    26. A simulator or measurement apparatus according to Claims 23 to 25, wherein the docking means comprises one or more springs which urge a joint on the connecting means to a position or range of positions corresponding to the position or range of positions which the joint may take when the engagement members commence engagement with each other.

30    27. A simulator or measurement apparatus according to any one of Claims 23 to 26, wherein the docking means includes a docking sensor means which comprises a sensor and sensor target; the sensor target is fixed to or associated with the interconnecting member between the

ball and the first joint and the sensor is fixed to or associated with the base; and the sensor means is operable to determine when the ball is in the starting position, by detecting contact or proximity between the sensor and the sensor target.

5 28. A simulator or measurement apparatus according to Claim 27, wherein the sensor target comprises a magnet and the sensor is operable to detect changes in magnetic field.

10 29. A simulator or measurement apparatus according to any of the preceding claims, wherein the ball game is golf in which the ball is hit in a range of golf shots, including a drive and a putting shot.

15 30. A simulator or measurement apparatus, for use in a ball game where a ball is hit from a stationary position, the apparatus including a ball, a connecting means and a base, wherein the ball is connected by the connecting means to the base and wherein the connecting means comprises an elongated rigid member between the ball and a joint connected to the base, or to other parts connected to the base, and about which the arm principally moves when the ball is struck characterised in that the elongated rigid member is manufactured from high strength-to-weight material; all or part of its external surface is tapered with its minimum dimensions closer to the ball; and the inertia of the connecting means about the joint is significantly less than the inertia of the ball about the joint.

20 31. A simulator or measurement apparatus according to Claim 30, wherein the ball game is golf and the ball is a real or simulated golf ball.

25 32. A simulator or measurement apparatus according to Claim 30 or Claim 31, wherein the length of the elongated rigid member, measured from the centre of the ball to the centre of the joint about which the arm principally moves when the ball is struck, is between 150 mm and 200 mm.

33. A simulator or measurement apparatus according to anyone of Claims 30 to 32, wherein the elongated rigid member is hollow.

34. A simulator or measurement apparatus according to any one of Claims 30 to 33, wherein  
5 the elongated rigid member is of circular cross section; its outer diameter in the region adjacent the ball is in the range 8-14 mm; and its outer diameter in the region away from the ball is in the range 14-20 mm.

35. A simulator or measurement apparatus according to any one of Claims 30 to 34, wherein  
10 the elongated rigid member has an internal bore, substantially of circular cross section; and its internal diameter is in the range 5-9 mm.

36. A simulator or measurement apparatus according to any one of Claims 30 to 35, wherein the elongated rigid member is manufactured from hardened aluminium alloy or hardened steel.  
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37. A simulator or measurement apparatus according to Claim 36, wherein the elongated rigid member is manufactured from hardened aluminium alloy, grade 7075 T6.

38. A simulator or measurement apparatus according to any one of Claims 30 to 37, wherein  
20 the ball has a medium coefficient of restitution or compression.

39. A simulator or measurement apparatus according to any one of Claims 30 to 38,  
wherein the ball has a coefficient of restitution corresponding to a compression of approximately 90.  
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40. A simulator or measurement apparatus according to any one of Claims 30 to 39, wherein the elongated rigid member and components attached to the elongated rigid member are arranged such as to minimise mass and to position it as close as possible to the joint about which the elongated rigid member principally moves when the ball is struck.

41. A simulator or measurement apparatus according to any one of Claims 30 to 40, wherein the ball game is golf in which the ball is hit in a range of golf shots, including a drive and a putting shot.

5 42. A simulator or measurement apparatus, for use in a ball game where a ball is hit from a stationary position, the apparatus including a ball, a connecting means, a base and a measurement means, where the ball is connected by the connecting means to the base, characterised in that the connecting means comprises an elongate member which is connected to the ball; the elongate member and the ball are operable to rotate collectively about an axis 10 which is the elongate axis of the elongate member; the apparatus includes a sensing means which is operable to measure rotation of the shaft; and the sensing means communicates with the measurement means.

15 43. A simulator or measurement apparatus according to Claim 42, wherein the elongate member is a rigid member such as a rigid shaft.

44. A simulator or measurement apparatus according to Claim 42 or 43, wherein the sensing means is associated with the distal end of the elongate member.

20 45. A simulator or measurement apparatus according to Claim 44, wherein the sensing means comprises a vane with irregularities; the vane is connected to the elongate member; the sensing means further comprises a detecting means which is operable to detect the passage of irregularities on the vane; the sensing means communicates with the measurement means; and the measurement means is operable to measure the rotation speed of the ball.

25 46. A simulator or measurement apparatus according to any one of Claims 42 to 45, wherein the elongate member is supported by one or more bearing members in the region adjacent its distal end; and is unsupported by bearing members in the region adjacent the ball.

47. A simulator or measurement apparatus according to any one of Claims 42 to 46, wherein the measurement means is operable to measure the linear speed of the ball and is operable to estimate the loft of the ball from measurement of the rotation speed and linear speed of the ball.

5 48. A simulator or measurement apparatus according to any one of Claims 42 to 47, wherein the ball game is golf in which the ball is hit in a range of golf shots, including a drive and a putting shot.

49. A simulator or measurement apparatus, for use in a ball game where a ball is hit from a  
10 stationary position, the apparatus including a ball, a connecting means, a base and a measurement means, where the ball is connected by the connecting means to the base, characterised in that the connecting means comprises a rigid construction; the measurement means includes an electromagnetic wave circuit, such as an optic circuit; a bridging means on the circuit which is operable to allow transmission or interruption of the electromagnetic waves;  
15 a member with irregularities which is connected to the connecting means, where the irregularities are operable to transmit or impede the electromagnetic waves in the bridging means; the member with irregularities and the bridging means are each located on parts of the connecting means which move relative to each other; and the circuit carrying the electromagnetic waves is an elongate circuit which is connected to remotely located electronic  
20 components.

50. A simulator or measurement apparatus according to Claim 49, wherein the member with irregularities is located on a region of the connecting means which is nearer to or more directly connected to the ball, than is the bridging means.

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51. A simulator or measurement apparatus according to either Claim 49 or 50, wherein the circuit carrying the electromagnetic waves comprises elongate fibres.

30 52. A simulator or measurement apparatus according to Claim 51, wherein the elongate fibres are polymer fibres.

53. A simulator or measurement apparatus according to any one of Claims 49 to 52, wherein the bridging means comprises spaced apart opposing ends of two fibres.

5 54. A simulator or measurement apparatus according to Claim 53, wherein the bridging means includes a slot with substantially parallel sides; the slot is positioned between the member with irregularities and the end of a fibre; the parallel sides are substantially orthogonal to the direction of motion of the member with irregularities and are spaced apart less than the width of the fibre; and the slots are positioned adjacent either or both of the fibres which emit  
10 or receive the electromagnetic waves.

55. A simulator or measurement apparatus according to any one of Claims 49 to 54, wherein the member with irregularities is a disk vane, or a vane comprising a segment of a disk, with regularly pitched radial slots on its perimeter.

15 56. A simulator or measurement apparatus according to Claim 55, wherein the vane comprises a thin metal material in the region of the slots, such as stainless steel with a thickness of around 0.2 mm, and the slots are produced by a process of high dimensional accuracy, such as photo etching, with an accuracy of around  $\pm 10\%$  of material thickness.

20 57. A simulator or measurement apparatus according to Claim 55 or 56, wherein the slot width and tooth width on the vane are each of approximately the same width as the slot in the bridging means.

25 58. A simulator or measurement apparatus according to any one of Claims 55 to 57, wherein the slot width and tooth width on the vane, and the slot in the bridging means, each have a width in the range 0.2 mm to 0.3 mm.

61. A simulator or measurement apparatus according to Claim 60, wherein the distance between fibre ends in the bridging means is 1.5 to 2.5 times the width of the slot in the bridging means.

5 59. A simulator or measurement apparatus according to any one of Claims 49 to 58, wherein the circuit carrying the electromagnetic waves is routed across a pivoted joint on the connecting means; and a portion of the circuit is aligned along the axis of the pivoted joint.

10 60. A simulator or measurement apparatus according to Claim 59, wherein the circuit carrying the electromagnetic waves comprises fibres; the shaft of the pivoted joint comprises a central passage along part of its axis; a portion of the fibres are arranged loosely and are routed through the central passage; and the opposing portions of the fibres in the central passage are connected to the portions of the circuit on each side of the pivoted joint.

15 62. A simulator or measurement apparatus according to any one of Claims 49 to 61, which includes two bridging means and at least two receiver circuits carrying electromagnetic waves; where the irregularities are regularly pitched; the two bridging means are set out of phase with one another with respect to the irregularities; and the measurement means is operable to detect false signals from the receiver circuits.

20 63. A simulator or measurement apparatus according to Claim 62, wherein the two bridging means are asymmetrically set out of phase with one another.

25 64. A simulator or measurement apparatus according to Claim 62, wherein the two bridging means are located such that one is one half slot away from the other, or is a whole number of slots plus one half slot away from the other.

65. A simulator or measurement apparatus according to any one of Claims 49 to 64, wherein the measurement means includes a timing means; the irregularities are regularly pitched; and

the measurement means is operable to interpolate measurement between or subsequent to the detection of irregularities.

66. A simulator or measurement apparatus according to any one of Claims 49 to 65, wherein

5 the ball game is golf in which the ball is hit in a range of golf shots, including a drive and a putting shot.

67. A simulator or measurement apparatus, for use in a ball game where a ball is hit from a stationary position, the apparatus including a ball, a connecting means, a base and a

10 measurement means, wherein the ball is connected by the connecting means to the base, characterised in that the connecting means is operable to allow the ball to spin about two different set axes; the measurement means is operable to measure the rates of rotation about these two set axes; the measurement means is operable to determine the rotation characteristics which the ball would have had about its natural spin axis if it had not been restrained by the set

15 axes.

68. A simulator or measurement apparatus according to Claim 67, wherein the rotation characteristics include or relate to the back spin and side spin of the ball.

20 69. A simulator or measurement apparatus according to Claim 67 or 68, which includes a controller means and an actuator means, and is operable to alter the inclination of the axis between the different set axes positions.

25 70. A simulator or measurement apparatus according to Claim 69, which is operable to repeatedly alter the axis between the different set axes positions; and the measurement means is operable to ascertain average values to more accurately determine the rotation characteristics which the ball would have had about its natural spin axis if it had not been restrained by the set axes.

71. A simulator or measurement apparatus according to either Claim 69 or 70, which is operable to alter the axis between the different set axes positions; and the measurement apparatus is operable to determine the similarity of characteristics of shots taken and to evaluate the accuracy of the determination of the rotation characteristics which the ball would have had about its natural spin axis if it had not been restrained by the set axes.

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72. A simulator or measurement apparatus according to any one of Claims 67 to 71, which is operable to alter the axis between the two different set axes positions without substantially altering the height or position of the ball.

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73. A simulator or measurement apparatus according to Claim 72, which comprises a quadrilateral pivoting arm arrangement with pivots at each corner of the quadrilateral arrangement; the quadrilateral arrangement comprising a base side which is connected to that part of the apparatus which is stationary when the axis is changed between the different axis settings; and also comprises a ball support side, which is opposite to the base side, and is connected to the supports for the ball rotation axis; the distance between the pivots on the base side being different to the distance between the pivots on the ball support side.

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74. A simulator or measurement apparatus according to Claim 73, wherein the distance between the pivots of the quadrilateral pivoting arm arrangement on the base side is greater than the distance between the pivots on the ball support side; the ball is closer to the ball support side than to the base side; and the base side is vertical or within about 20° of vertical.

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75. A simulator or measurement apparatus according to of Claim 73 or Claim 74, wherein the axial lengths of the pivots of the quadrilateral pivoting arm arrangement are much longer than the distance between the pivots.

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76. A simulator or measurement apparatus according to Claim 72, wherein the axis tilt means comprises a curved sliding or rolling means which corresponds to a portion of an arc of a circle where the centre of the circle corresponds to the position of the centre of the

ball and the ball shaft lies along a radius of the arc; the curved sliding or rolling means being operable to rotate the axis between one tilt angle and the other while the ball centre remains at a fixed height at the centre of the arc.

- 5      77. A simulator or measurement apparatus according to any one of Claims 67 to 76, which includes an actuator means which is operable to urge the connecting means to alter the axis between the two different set axes positions.
- 10     78. A simulator or measurement apparatus according to Claim 77, wherein the actuator means comprises an electric motor, a movement limiting means and an electric motor controller means; the movement limiting means being operable to mechanically limit the movement of the actuator means to a range of positions corresponding to the range of positions of the axis between the two different axes positions; and the electric motor controller means is operable to detect changes in the electrical characteristics of the motor when the actuator is mechanically limited by the movement limiting means and to stop the electric motor when such changes are detected.
- 15     79. A simulator or measurement apparatus according to any one of Claims 67 to 74, wherein the ball game is golf in which the ball is hit in a range of golf shots, including a drive and a putting shot.
- 20     80. A simulator or measurement apparatus, for use in a ball game where a ball is hit from a stationary position, the apparatus including a ball, a connecting means, a base and a measurement means, wherein the ball is connected by the connecting means to the base, characterised in that the apparatus includes sensor means which produce input signals when the ball is hit; and the measurement means is operable to determine the motion characteristics of an unconnected ball by comparison of these input signals to input signals corresponding to previous shots with known motion characteristics.

81. A simulator or measurement apparatus according to Claim 80, wherein the measurement means includes an artificial neural-type intelligence means.

82. A simulator or measurement apparatus according to Claim 80, wherein the artificial  
5 neural-type intelligence means has been trained using a ball striking means.

83. A simulator or measurement apparatus according to Claim 82, wherein training inputs to  
the artificial neural-type intelligence means are determined by striking the connected ball with  
the ball striking means, and training outputs to the artificial neural-type intelligence means are  
10 determined by striking an unconnected ball with the ball striking means in like manner and  
measuring its motion characteristics.

84. A simulator or measurement apparatus according to Claim 81, wherein  
the measurement means is operable to pre-process the input signals before presenting  
15 information to the artificial neural-type intelligence means.

85. A simulator or measurement apparatus according to Claim 84, wherein  
the measurement means is operable to pre-process the input signals to convert them to inputs  
relating to the relative position of the connected ball.

20 86. A simulator or measurement apparatus according to any one of Claims 80 to 85, wherein  
the measurement means is operable to categorise types of shots from analysis of the inputs and  
to apply differing criteria in determining the motion characteristics of an unconnected ball,  
depending on the results of the categorisation.

25 87. A simulator or measurement apparatus according to Claim 86, wherein the ball game is  
golf and the categories include drive shots, putting shots, intermediate shots and ball types.

30 88. A simulator or measurement apparatus according to any one of Claims 80 to 87, wherein  
the measurement means is operable to be selectively adjusted to show the motion characteristics

which would result with different playing conditions, including different ball characteristics and different ground characteristics.

89. A simulator or measurement apparatus according to any one of Claims 80 to 88, wherein  
5 the measurement means is operable to be selectively adjusted to allow calibration or alteration of  
the interpreted motion characteristics.

90. A simulator or measurement apparatus, for use in a ball game where a ball is hit from a  
stationary position, the apparatus including a ball, a connecting means and a base, wherein the  
10 ball is connected by the connecting means to the base, and wherein the ball is a golf ball or  
simulated golf ball, characterised in that the connecting means is of rigid construction; and the  
connecting means comprises projections or flanged components within the ball which are  
operable to resist forces acting in a direction parallel to the principal axis of the connecting  
means, or torsional forces acting around the principal axis of the connecting means, by  
15 compression of the elastic material of the ball, or reconstituted parts of the ball, against the  
projections or flanged components.

91. A simulator or measurement apparatus according to Claim 90, wherein the inertia of the  
connecting means is significantly less than the inertia of the ball.

20 92. A simulator or measurement apparatus according to Claim 90 or Claim 91, wherein the  
surface of the material of the ball, or reconstituted parts of the ball, is operable to move relative  
to the surface of the connecting means, with which it is in contact.

25 93. A simulator or measurement apparatus according to any one of Claims 90 to 92, wherein  
the projections or flanged components are adjacent the end of the connecting means and are  
located in the region of the centre of the ball.

94. A simulator or measurement apparatus according to any one of Claims 90 to 93, which includes a polymer plug fixed in a hole formed in the ball; and the polymer plug comprises an elastic material.

5 95. A simulator or measurement apparatus according to Claim 94 wherein the external surface of the polymer plug is strongly bonded to the internal surface of the hole formed in the ball.

10 96. A simulator or measurement apparatus according to Claim 94 or Claim 95, wherein the material at the external surface of the polymer plug has elastic characteristics which are substantially similar to, or compatible with, the elastic characteristics of the contacting material of the ball.

15 97. A simulator or measurement apparatus according to Claim 96, wherein the polymer plug comprises a coaxial sleeve surrounding a portion of the connecting means; and the connecting means is axially restrained by the polymer plug bearing against the projections or flanged components.

20 98. A simulator or measurement apparatus according to any one of Claims 94 to 97, wherein the polymer plug, and the hole formed in the ball to receive the polymer plug, each have an external surface formed as the frustum of a cone, orientated with the larger diameter closer to the exterior of the ball.

25 99. A simulator or measurement apparatus according to any one of Claims 90 to 98, which comprises a flexible reinforcing member fixed to the external surface of the ball in the annular region surrounding the connecting member.

100. A simulator or measurement apparatus according to any one of Claims 90 to 99, wherein the ball is comprised of at least two concentric layers of material of different hardness and 30 where the material in an inner layer is harder than the material in an outer layer.

101. A simulator or measurement apparatus according to any one of Claims 90 to 100, wherein the ball game is golf in which the ball is hit in a range of golf shots including a drive and a putting shot.

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102. A simulator or measurement apparatus according to any one of the preceding claims, which includes a ball height setting means which is operable to set the ball over a range of heights above a datum level prior to the shot, wherein the ball height setting means includes a rack and pinion or a plurality of racks and pinions, wherein the pinions are mounted on a common shaft; the rack is vertical and is connected to the connecting means which supports the ball; and the pinion is operable to raise the height of the ball and connecting means by rotation of the pinion in engagement with the rack.

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103. A simulator or measurement apparatus according to any one of Claims 1 to 101, which includes a ball height setting means which is operable to set the ball over a range of heights above a datum level prior to the shot, wherein the ball height setting means includes a parallel motion linkage which comprises a plurality of arms of equal length, with each connected to a pivot on the axis tilt means and a pivot connected to the base; the axes of the pivots are orientated in a direction which is orthogonal to the plane of the intended movement of the ball.

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104. A simulator or measurement apparatus according to Claim 102 to 103, wherein the ball and the connecting means are maintained at the set height by a ratchet and pawl arrangement; the ratchet pitch determining steps in the setting height; and the ratchet is operable to be disengaged to allow the ball to return to its lowest setting.

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105. A simulator or measurement apparatus according to any one of the preceding claims, which includes a retardation means which is operable to bring the ball to rest after a shot is taken; the retardation means includes a buffer means which is operable to absorb energy from the ball; and the buffer means comprises a resilient ball contact surface.

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106. A simulator or measurement apparatus according to Claim 105 which includes a deflector means which is operable to deflect the ball onto the buffer means; the deflector means comprises a ball contact surface which is inclined at an angle which lies between the angle of the surface of the buffer means and the range of angles of approach of the ball to the deflector means; and all or part of the ball contact surface is disposed in a plane which is horizontal or close to horizontal.

107. A simulator or measurement apparatus according to Claim 106 where the buffer means is operable to recoil away from its start position when hit by the ball.

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108. A simulator or measurement apparatus according to any of Claims 105 to 107, wherein the ball describes a radial orbit about a principal centre of orbit and where the deflector means or buffer means is located at or just before the region where the ball has described an orbit of about 180° about the principal centre of orbit.

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109. A simulator or measurement apparatus according to any one of the preceding claims, wherein the ball is connected to a ball connection member which comprises part of the connecting means; the ball connection member is connected to other parts of the connecting means by a screw threaded joint; and the screw threaded joint is arranged so that it is urged in 20 a tightening direction of rotation by the back spin of the ball.

110. A simulator or measurement apparatus according to Claim 109, wherein the screw threaded joint comprises a right handed thread for apparatus intended for right handed players and a left handed thread for apparatus intended for left handed players.

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111. A simulator or measurement apparatus according to Claim 109 or 110, wherein the ball connection member comprises a rigid elongate member; and the screw threaded joint is located at the end of the ball connection member which is furthest from the ball.

112. A simulator or measurement apparatus according to any of Claims 109 to 111, which includes a stopping means and a casing, wherein the screw threaded joint is surrounded by the casing; the stopping means is operable to stop rotation of the part of the screw threaded joint which is not located on the ball connection member; the stopping means comprises a hole in  
5 the screw threaded joint and a hole in the casing; the holes are arranged so that they can be aligned at certain rotation angles of the screw threaded joint relative to the casing; and the holes are arranged so that they are accessible for insertion of a pin or similar object when the holes are aligned.
- 10 113. A simulator or measurement apparatus according to any one of the preceding claims, which includes a sound synthesiser means which is operable to replicate or exaggerate the sound of an unconnected ball when a shot is taken.
- 15 114. A simulator or measurement apparatus substantially as herein described with reference to and as shown in the accompanying drawings.
- 20 115. A method of simulating or measuring the characteristics of a ball when hit from a stationary position using a simulator or measurement apparatus as claimed in any one of the preceding claims.
116. The features defined in the foregoing description, claims and drawings or any obvious equivalent or combination thereof.